Photoluminescence Dependence on Heterointerface for MOCVD Grown GaInNAs/GaAs QWs

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We have evaluated the optical quality of GaInNAs/GaAs quantum wells (QWs) grown by metalorganic chemical vapor deposition (MOCVD) with different supply sequences of nitrogen (N) source at heterointerfaces. We found that there are two types of PL degradations of GaInNAs by MOCVD.

The GaAs based long-wavelength GaInNAs laser has been attracting a great interest for light wave network applications [1]. Especially, the GaInNAs/GaAs system is expected and studied as an active layer of long-wavelength vertical-cavity surface-emitting lasers (VCSELs) [2], since most of well-establish VCSEL technologies on GaAs substrate can be applied. However, there have been a few reports discussing on PL degradation mechanisms of GaInNAs grown by MOCVD. In this paper, we pay attention to the heterointerface effect on the optical quality.

The gas flow sequence for GaInNAs/GaAs QWs growth is shown in Fig. 1. The time Δt_1 and Δt_2 determine the growth condition of heterointerfaces structure. For example, by setting $\Delta t_1>0$ the DMHy supply will be started after starting the group III supply. If Δt_1 is larger than 4.8s which is corresponding to the growth of 1ML, a N-free GaInAs layer will be formed at the interface. Δt_1 can also take minus value. For this case, the DMHy supply will be started before starting the group III supply. It may be effective to confirm the As/N exchange reaction like P/As exchange at the heterointerface of GaInAs(P)/InP.

47Å(16ML)-thick GaInNAs QWs were grown by varying Δt_1 from -2s to 12s (corresponding to -0.3ML to 2.7ML) with fixed Δt_2=0s. The peak wavelength and intensity dependence of room temperature PL against Δt_1 are shown in Fig. 2. The PL peak wavelength was blue-shifted by about 20nm with changing Δt_1 from 0ML to 0.3ML and the intensity tends to be increased with increasing Δt_1. This phenomenon suggests the importance of heterointerface control for the growth of GaInNAs. We considered that the increased wavelength for $\Delta t_1 \leq$0ML is caused by the formation of a GaNAs layer with a relatively large N content at the interface. The DMHy flow for growing GaInNAs is larger than that for GaNAs to achieve the same N content. As for another possible effect of GaNAs formation, the inhomogeneous growth of GaInNAs on GaNAs layer which could roughen the heterointerface. In this case, clusters of In caused by rough interface may elongate the emission wavelength and also result in poor crystal quality. We have also grown GaInNAs QWs with delayed DMHy supply for Δt_1= 2.7ML. The PL peak wavelength was blue-shifted by about 40nm in comparison with Δt_1=0.3ML. A N-free GaInAs layer was formed at the interface because the DMHy flow was delayed by more than 1ML. A large blue-shift was caused due to the increase of averaged bandgap energy of the GaInNAs QWs by decrease of GaInNAs volume in total QW volume. In QWs with Δt_1=2.7ML, the PL intensity was increased about three times higher than that of QWs with Δt_1=0ML as shown in Fig. 2. It is considered that the relative GaInNAs volume which is the GaInNAs proportion in the QW also affects its optical quality.

We have grown GaInNAs QWs with inserting relatively thick GaInAs layers by varying Δt_1 and $\Delta t_2=\Delta t_1$ resulting in relative GaInNAs volume of 0%~100%. The well thickness is kept to be 60Å. We call this structure as GaInAs intermediate layer (IML). The dependence of PL properties including intensity, the FWHM and peak wavelength on the relative GaInNAs volume is shown in Figs. 3(a) and (b). The PL intensity increased with decreasing relative GaInNAs volume in the QW. This result indicates another mechanism of quality degradation of GaInNAs, the non-radiative center caused by N incorporation which is introduced uniformly in the GaInNAs layer. By comparison with QWs with relative GaInNAs volume of 87% to that of 100%, the FWHM was decreased by inserting GaInAs layers which prevent the fluctuation of the potential of the well. By decreasing relative GaInNAs volume in the QW results in reducing non-radiative center, the FWHM tends to be decreased.

A GaInAs IML structure may help the wavelength extension of GaInNAs QW with high optical quality because the insertion of appropriately designed GaInAs IML layer to GaInNAs QW extends wavelength with small optical quality degradation [3].

In conclusion, we have found that the gas flow sequence of DMHy at heterointerface affecting the optical quality of GaInNAs/GaAs grown by MOCVD. We pointed out there are two mechanisms of crystal quality degradation of GaInNAs. One is the formation of GaNAs layer at the interface that will cause a wavelength extension and crystal quality degradation. Another mechanism which was confirmed by changing relative GaInNAs volume is the non-radiative center caused by N incorporation.

Reference

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[2] K. Iga; IPRM'96, ThA1-1 (1996).
[3] E. Gouardes, T. Miyamoto, M. Kawaguchi, T. Kondo, F. Koyama, and K. Iga; will be discussed elsewhere

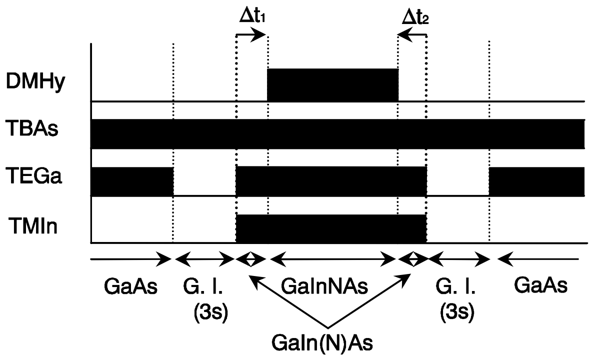


Fig. 1 Gas flow sequence of GaInNAs QWs

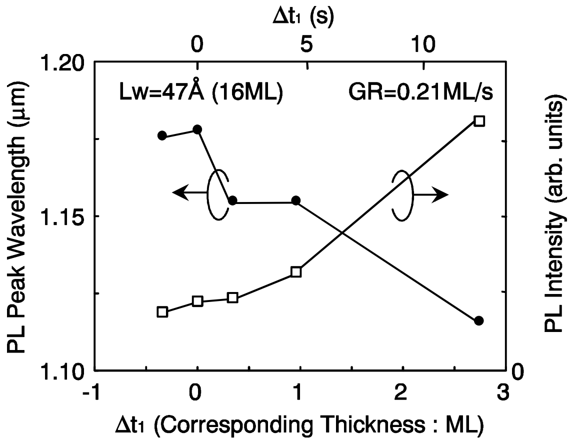
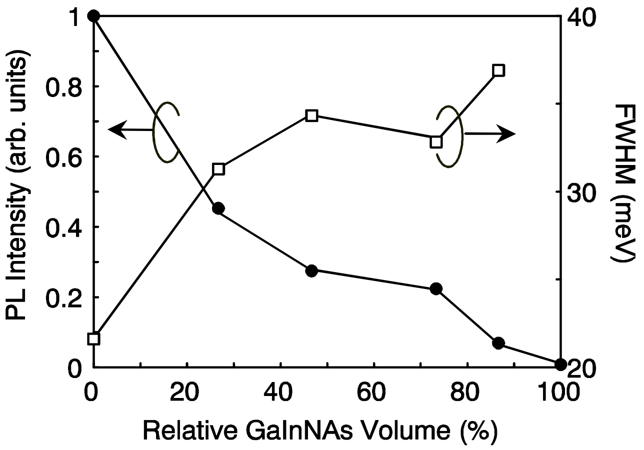
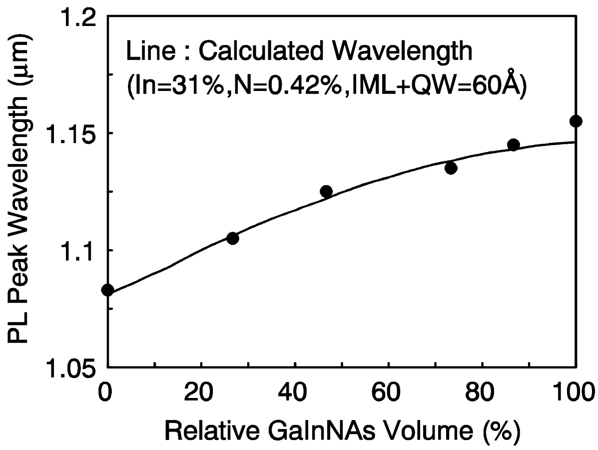


Fig. 2 PL peak wavelength and intensity dependence on DMHy flow sequence at heterointerface of GaInNAs/GaAs. Δt_1<0 means starting the DMHy supply before starting the group III supply in Fig. 1



(a) PL intensity and FWHM



(b) PL peak wavelength

Fig. 3 PL properties dependence on the relative GaInNAs volume for GaInNAs(N=0.42%) QWs with GaInAs-IML